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ORIGINAL PAPER

The effect of single-tree selction system on soil properties in an oriental beech stand of Hyrcanian forest, north of Iran

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Abstract: A case study was conducted in beech forests of northern Iran to determine the effect of the created gaps on some soil properties in beech stand. Changes of soil properties in small (60−150 m^2), medium (151−241 m^2), large (242−332 m^2) and very large (333−550 m^2) gaps, as well as under closed stands were studied eight years after the gap creation. Soil samples were taken from three depths, 0−10, 10−20 and 20−30 cm. The gaps were different from their around undisturbed stands in terms of the following soil parameters: Mg^{+2} concentration of 0−10 cm at medium gap size, bulk density of 10−20 cm at very large gap size as well as K^+ and Ca^{+2} concentrations at 20−30 cm at small and large gap sizes, respectively. Furthermore, the size of the gaps had no effect on soil characteristics through the whole profile. Water saturation percent (Sp %) at 0−10cm as well as P and Mg^{+2} at 20−30 cm was different amongst undisturbed stands around different gap sizes. The center and the edges of the gap were different only in terms of organic carbon at the depth of 10−20 cm. Significant differences were observed between gaps and closed canopy regarding P and Ca^{+2} at depth 0−10 cm and 10−20 cm, respectively. It can be concluded that applied silvicultural system for harvesting trees which created these gaps might be suitable for conservation and forest management in the region.

Keywords: gap; soil; *Fagus orientalis*; single-tree selection system; northern Iran

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Introduction

Forests, as dynamic systems, are exposed to constant changes (Stancioiu and O'Hara 2005). Forest ecosystem is constantly influenced by natural disturbances (e.g. storm) or man-made ones (e.g. harvesting) and these disturbances may have serious impact on the ecosystem (Legout et al., 2009). Natural and artificial disturbances can cause injuries in trees, which in turn, creates openings which are called canopy gaps (Yamamoto, 2000). Microclimates within and around gaps immediately change after gap creation (Zhu et al. 2007). The magnitude and duration of increasing resources depend on characteristics of gaps (e.g. gap size, form, height and diameter of trees bordering gaps) and adjacent stand structure (Gagnon et al., 2004).

Disturbance such as harvesting changes the soil fertility and nutrition balance (Boyes et al. 2010). Artificial gaps provide the possibility of observing the changes in soil (Muscolo et al. 2007). Soil and the stand features are of great importance for management, tree-species selection, health and productivity of ecosystem (Ponge and Chevalier 2006). Foresters always emphasize on the understanding of soil physico-chemical features in evaluating site capacity to support productive forests (Schoenholtz et al. 2000). To conserve and improve soil quality, promoting forest management methods are of special importance (Muscolo et al. 2010).

Many studies have been carried out to investigate gap effects on soil properties (Bauhus 1996; Clinton 2003; Boudreau and Laws 2005; Muscolo et al. 2008; Sharenbroch and Bockheim 2008; Thiel et al. 2009). Caspian forests of Iran have been

harvested under different silvicultural operations such as shelterwood and selection systems (Sagheb-Talebi et al. 2002; Tabari et al. 2007), which created different gap sizes in such forests. So far, no studies have been conducted to explore the effects of gap size on soil properties in hyrcanian beech forests. Consequently, this study aimed to investigate the effects of gaps in different sizes created by single-tree selection system in 2000 on some physico-chemical properties of soil within gaps in comparison to those under undisturbed neighbouring beech stands in northern Iran. The main hypotheses of this study are: (1) Soil properties in gaps are different from the soil properties in the surrounding undisturbed stands eight years after harvesting; (2) The size of the gap influences on the soil properties. Understanding the ecological changes within gaps and comparing it with the undisturbed stands can be helpful in forest management and play a significant role in evaluating silvicultural systems.

Materials and methods

Study area

The study was carried out in a beech forest of 113 ha located at Sari, northern Iran (36°13'–36°12' N, 53°23'–53°03' E, Fig.1). The forest is dominated by uneven aged oriental beech (*Fagus orientalis* L.) and less frequent species are hornbeam (*Carpinus betulus* L.), maple (*Acer velutinum* Boiss) and alder (*Alnus subcordata* C.A.M.). The parent material of this area is limestone and dolomite limestone, belonging to upper jurassic and lower cretaceous period. The soil of this area is classified as forest brown with suitable penetration and biological activities according to FAO (1987). The mean annual temperature, rainfall and relative humidity are 10.5 °C, 858 mm and 75.2%, respectively. The climate is humid based on Domarten method. Sixteen gaps in four size classes, small (60–150 m^2), medium (151–241 m^2), large (242–332 m^2) and very large (333–550 m^2), with four replicates for each, were selected for investigations. The area of extended gaps was calculated by measuring its long and short axes as ellipse shape (Runkle 1981).

Soil sampling and analysis

The field study was conducted in autumn 2009. Soil samples were taken from centre of gaps, the cardinal points of gaps, and adjacent undisturbed stands at three depths (0–10, 10–20 and 20–30 cm, Fig. 2). The sampling points of undisturbed stands are 20 m far from edge of each gap. Collected samples from the edge of each gap as well as the undisturbed adjacent stands were mixed to make a composite representative samples. Subsequently, we had three soil samples from each gap: one from centre, two composite samples from cardinal points and undisturbed adjacent stands. Soil samples were dried at 40°C and sieved (2 mm). Bulk density (BD) and soil water saturation percentage (Sp %) was measured by Plaster (1985) method. Organic carbon (O.C), total N, available phosphorus (P), pH, exchangeable Ca, K and Mg were determined by following Page (1992) method.

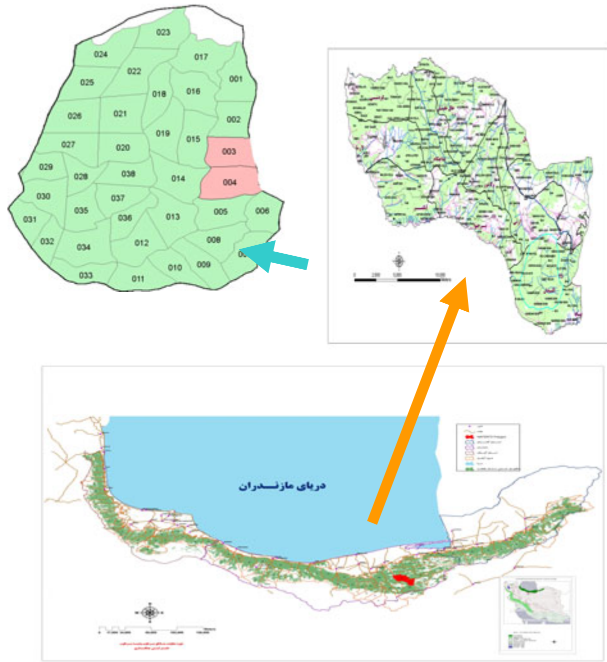

Fig. 1 Location of study area (compartments 3, 4), Northern Iran

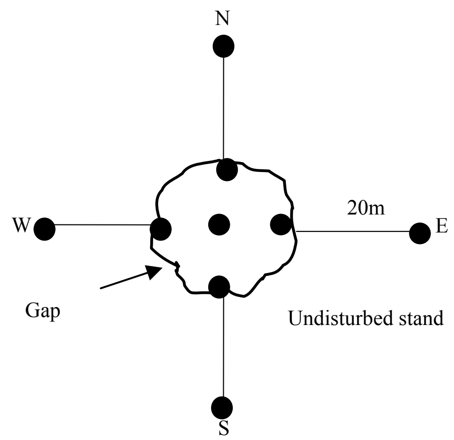

Fig. 2 Layout of plots of soil sampling

Statistical analysis

Data were analysed using one-way ANOVA, followed by mean comparisons using the S.N.K test. All reported differences were statistically significant at $p \le 0.05$. Independent T test was used to compare means of soil properties of the same depths at each gap with its adjacent undisturbed stands as well as between the center and the edge of gaps and between gaps and closed canopy. Standard Error (SE) was calculated to show distribution of data around the mean. The SPSS (version 13.0) was used for statistical analysis.

Results

According to the results of the study, the size of the gaps had no effect on soil characteristics through the whole profile (Table 1). Examining the soil properties among the undisturbed stands around different gaps showed that they were different in terms of Sp% at the depth of 0−10cm as well as P and Mg^{+2} at the depth of 20−30 cm (Table 2). No differences were observed regarding other investigated soil parameters in the adjacent undisturbed stands of gaps. Furthermore, there were differences between gaps and their surrounding undisturbed stands in the following soil parameters (Table 3): medium gap size at the depth of 0−10 cm in terms of Mg^{+2} concentration, small and large gap sizes at 20−30 cm in terms of Ca^{+2} and K^{+} concentrations, and very large gap size at 10−20 cm for BD. By examining the center and the edges of the gaps (Table 4), it was revealed that there were no significant differences considering most soil feature except from the organic matters at the depth of 10−20 cm (p < 0.05). There was significant difference between gaps and the adjacent closed canopy regarding P and Ca^{+2} at depth 0-10 and 10−20 cm respectively (Table 5).

Table 1. Soil properties within different gap size through the whole profile in *Fagus orientalis* forest, northern Iran

Depth (cm)	Gaps	Sp (%)	BD (gcm-3)	pH (H2O)	Soil nutrients					
							(mg·kg^{-1})			
					O.C%	N%	P	K+	Ca2+	Mg2+
0-10	Small	67.75^{A} (2.88)	1.28^{A} (0.07)	5.26^{A} (0.17)	3.49^{A} (0.60)	0.34^{A} (0.05)	8.03^{A} (2.53)	0.68^{A} (0.05)	0.36^{A} (0.06)	0.38^{A}(0.12)
	Medium	63.25^{A} (3.56)	1.23^{A} (0.05)	5.33^{A} (0.14)	3.08^{A} (0.64)	0.29^{A} (0.05)	7.05^{A} (1.55)	0.68^{A} (0.03)	0.18^{A} (0.06)	0.09^{A} (0.01)
	Large	67.87^{A} (2.68)	1.22^{A} (0.055)	5.26^{A} (0.12)	2.51^{A} (0.35)	0.24^{A} (0.03)	5.29^{A} (1.12)	0.69^{A} (0.07)	0.27^{A} (0.04)	0.20^{A} (0.04)
	Very large	68.38^{A} (3.23)	1.34^{A} (0.07)	5.33^{A} (0.19)	2.88^{A} (0.21)	0.27^{A} (0.02)	2.68^{A} (0.83)	0.73^{A} (0.41)	0.25^{A} (0.05)	0.28^{A} (0.08)
10-20	Small	62.87^{A} (3.23)	1.25^{A} (0.05)	5.11^{A} (0.16)	1.15^{A} (0.25)	0.28^{A} (0.10)	2.73^{A} (0.50)	0.68^{A} (0.06)	0.16^{A} (0.03)	0.35^{A} (0.06)
	Medium	60.88^{A} (3.39)	1.19^{A} (0.03)	5.36^{A} (0.13)	1.39^{A}(0.25)	0.13^{A} (0.02)	4.67^{A} (1.19)	0.61^{A} (0.03)	0.14^{A} (0.03)	0.20^{A} (0.02)
	Large	54.87^{A} (2.88)	1.16^{A}(0.05)	5.41^{A} (0.12)	1.44^{A} (0.52)	0.12^{A} (0.02)	4.90^{A} (0.75)	0.60^{A} (0.05)	0.21^{A} (0.02)	0.37^{A} (0.06)
	Very large	54.63^{A} (2.82)	1.13^{A} (0.01)	5.14^{A} (0.15)	1.06^{A} (0.22)	0.10^{A}(7.17)	10.1^{A} (7.17)	0.61^{A} (0.03)	0.13^{A} (0.03)	0.18^{A} (0.04)
20-30	Small	62.00^{A}(3.83)	1.20^{A} (0.05)	5.07^{A}(0.15)	0.83^{A}(0.15)	0.17^{A} (0.07)	2.15^{A} (0.51)	0.57^{A} (0.06)	0.14^{A} (0.02)	0.25^{A} (0.07)
	Medium	59.50^{A}(2.92)	1.12^{A} (0.03)	5.15^{A} (0.05)	11.91^{A} (10.72)	0.11^{A} (0.02)	4.12^{A} (0.95)	0.65^{A} (0.04)	0.15^{A} (0.02)	0.25^{A} (0.05)
	Large	60.13^{A} (4.16)	1.18^{A} (0.04)	5.41^{A} (0.13)	1.96^{A} (0.75)	0.15^{A} (0.05)	4.25^{A} (0.48)	0.67^{A} (0.04)	0.19^{A} (0.06)	0.20^{A} (0.03)
	Very large	50.57^{A} (1.46)	1.17^{A}(0.04)	5.16^{A} (0.17)	0.89^{A} (0.07)	0.07^{A} (0.01)	6.08^{A} (1.67)	0.69^{A} (0.52)	0.15^{A} (0.02)	0.24^{A} (0.06)

Sp: water saturation percentage; BD: Bulk density; O.C: Organic carbon; N: total nitrogen; P: available phosphorus; Ca: exchangeable Calcium; K: exchangeable Potassium; Mg: exchangeable Magnesium.The same letters indicate no significant (p<0.05) differences. Values presented as mean (SE).

Table 2. Soil properties within undisturbed stands surrounding gap classes through the whole profile in *Fagus orientalis* forest, Northern Iran

depth (cm)	Undisturbed stand	Sp (%)	BD (gcm^{-3})	pH (H_2O)	Soil nutrients					
							(mg·kg^{-1})			
					O.C%	N%	P	K^{+}	Ca^{2+}	Mg^{2+}
0-10	Small	72.12^{ab} (2.79)	1.39^{a}(0.04)	5.23^{a}(0.11)	3.59^{a}(0.40)	0.30^{a} (0.03)	2.50^{a}(0.88)	0.72^{a} (0.03)	0.30^{a} (0.08)	0.27^{a}(0.06)
	Medium	70.20^{ab}(2.64)	1.31^{a}(0.11)	5.43^{a}(0.14)	3.24^{a}(0.21)	0.29^{a}(0.05)	3.50^{a}(0.55)	0.57^{a} (0.09)	0.23^{a} (0.08)	0.54^{a}(0.21)
	Large	65.75^{a}(0.47)	1.23^{a}(0.07)	5.25^{a}(0.16)	2.51^{a}(0.40)	0.18^{a}(0.03)	3.70^{a}(0.84)	0.67^{a} (0.06)	0.18^{a} (0.04)	0.29^{a} (0.08)
	Very large	77.75^{b}(2.06)	1.39^{a}(0.04)	5.15^{a}(0.15)	3.09^{a}(1.01)	3.12^{a}(0.08)	3.95^{a}(1.09)	0.56^{a} (0.09)	0.18^{a} (0.06)	0.21^{a}(0.11)
10-20	Small	57.22^{a}(2.45)	1.18^{a} (0.30)	5.18^{a}(0.06)	1.60^{a} (0.31)	0.13^{a} (0.02)	2.25^{a}(0.37)	0.68^{a} (0.09)	0.15^{a} (0.03)	0.27^{a} (0.10)
	Medium	59.50^{a}(4.94)	1.21^{a} (0.78)	5.38^{a}(0.10)	1.48^{a} (0.18)	0.26^{a} (0.11)	4.60^{a}(0.61)	0.63^{a} (0.07)	0.23^{a} (0.03)	0.45^{a}(0.18)
	Large	49.75^{a}(2.43)	1.23^{a}(0.07)	5.26^{a}(0.17)	1.27^{a}(0.27)	0.13^{a} (0.02)	4.43^{a}(1.16)	0.49^{a} (0.02)	0.28^{a} (0.05)	0.23^{a} (0.03)
	Very large	57.5^{a}(4.19)	1.29 ^{a}(0.04)	5.3^{a}(0.08)	1.37^{a}(0.21)	0.27^{a}(0.09)	2.70^{a}(0.61)	0.66^{a}(0.05)	0.36^{a} (0.16)	0.47^{a} (0.17)
20-30	Small	59.00^{a}(3.34)	1.25^{a} (0.06)	5.00^{a}(0.20)	1.34^{a}(0.41)	0.14^{a} (0.05)	2.85^{ab}(0.12)	0.61^{a} (0.14)	0.31^{a}(0.07)	0.20^{a} (0.03)
	Medium	53.75^{a}(5.17)	1.26^{a} (0.09)	5.52^{a}(0.20)	1.04^{a}(0.05)	0.24^{a}(0.12)	3.80^{b}(0.63)	0.67^{a} (0.08)	0.27^{a} (0.13)	0.50^{b} (0.13)
	Large	61.00^{a}(6.20)	1.28^{a}(0.10)	5.13^{a}(0.11)	1.52^{a}(0.52)	0.14^{a} (0.04)	3.15^{ab}(0.21)	0.42^{a}(0.07)	0.16^{a} (0.04)	0.19^{a}(0.07)
	Very large	56.00^{a}(5.02)	1.25^{a} (0.04)	5.35^{a} (0.09)	0.74^{a} (0.05)	0.07^{a} (0.01)	1.80^{a}(0.43)	0.54^{a}(0.03)	0.32^{a}(0.15)	0.13^{a} (0.03)

Sp: water saturation percentage; BD: Bulk density; O.C: Organic carbon; N: total nitrogen; P: available phosphorus; Ca: exchangeable calcium; K: exchangeable Potassium; Mg: exchangeable Magnesium. The same letters indicate no significant (p<0.05) differences. Values presented as mean (SE)

Table 3 . Comparing soil properties between different sizes of gaps and adjacent closed canopy in different soil depths in *Fagus orientalis* forest

Depth (cm)	variables	Small gaps		Medium gaps		Large gap		Very large gaps	
		F-value	Sig.	F-value	Sig.	F-value	Sig.	F-value	Sig.
0-10	Sp%	0.13	0.375	3.47	0.245	4.14	0.597	4.01	0.084
	OC%	1.207	0.917	1.24	0.878	0.127	0.995	23.35	0.783
	pH	2.926	0.89	1.602	0.668	0.001	0.954	9.52	0.557
	N%	4.017	0.678	0.669	0.965	1.671	0.354	3.04	0.588
	P (mg·kg^{-1})	2.612	0.169	11.86	0.15	0.494	0.377	2.26	0.261
	K (mg·kg^{-1})	11.109	0.629	1.22	0.221	0.287	0.836	3.442	0.075
	Ca (mg·kg^{-1})	0.248	0.938	0.011	0.674	0.513	0.361	0.087	0.422
	Mg (mg·kg^{-1})	3.48	0.554	214.42	**0.009**	0.138	0.375	0.025	0.621
	BD (g·cm^{-3})	2.641	0.357	2.462	0.443	0.073	0.99	2.21	0.644
10-20	Sp%	2.87	0.264	0.067	0.822	0.259	0.279	0.036	0.575
	OC%	0.008	0.311	0.428	0.805	1.44	0.835	0.358	0.399
	pH	2.902	0.799	1.167	0.953	0.012	0.531	6.86	0.556
	N%	6.093	0.332	6.37	0.158	1.59	0.792	8.28	0.096
	P (mg·kg^{-1})	1.343	0.544	3.028	0.967	0.004	0.731	2.18	0.495
	K (mg·kg^{-1})	0.042	0.966	4.241	0.824	2.31	0.181	19.84	0.165
	Ca (mg·kg^{-1})	0.124	0.896	0.169	0.126	2.68	0.276	6.85	0.082
	Mg (mg·kg^{-1})	0.101	0.513	52.416	0.583	2.19	0.226	15.32	0.052
	BD (g·cm^{-3})	1.744	0.397	0.455	0.752	0.028	0.468	2.21	**0.004**
20-30	Sp%	2.809	0.627	0.125	0.318	0.231	0.907	2.7	0.221
	OC%	2.428	0.19	2.569	0.501	1.51	0.701	2.28	0.175
	pH	0.027	0.78	3.73	0.056	0.957	0.194	6.32	0.512
	N%	0.385	0.829	6.118	0.197	0.701	0.94	0.384	0.911
	P (mg·kg^{-1})	4.929	0.375	4.003	0.827	5.76	0.152	4.403	0.093
	K (mg·kg^{-1})	3.675	0.643	0.337	0.8	0.113	**0.012**	1.4	0.068
	Ca (mg·kg^{-1})	1.672	**0.022**	25.74	0.24	0.825	0.769	8.18	0.206
	Mg (mg·kg^{-1})	3.264	0.678	1.73	0.06	0.275	0.85	16.64	0.265
	BD (g·cm^{-3})	0.492	0.573	0.663	0.792	1.45	0.304	3.32	0.317

Sp: water saturation percentage, BD: Bulk density, O.C: Organic carbon, N: total nitrogen, P: available phosphorus. Ca: exchangeable Calcium, K: exchangeable Potassium and Mg: exchangeable Magnesium. Same as the following tables.

Table 4. Comparing soil properties between center and edge of gaps in different depths of soil in *Fagus orientalis* forest

Depth (cm)	variable	F value	Sig.
0-10	Sp%	0.64	0.74
	OC%	1.69	0.79
	pH	2.19	0.75
	N%	2.40	0.51
	P (mg·kg^{-1})	1.11	0.61
	K (mg·kg^{-1})	0.75	0.19
	Ca (mg·kg^{-1})	5.86	0.09
	Mg (mg·kg^{-1})	2.98	0.31
	BD (g·cm^{-3})	0.48	0.08
10-20	Sp%	1.72	0.34
	OC%	3.06	**0.03**
	pH	2.22	0.23
	N%	4.61	0.74
	P (mg·kg^{-1})	2.72	0.26
	K (mg·kg^{-1})	3.07	0.10
	Ca (mg·kg^{-1})	0.91	0.53
	Mg (mg·kg^{-1})	0.89	0.65
	BD (g·cm^{-3})	1.02	0.47
20-30	Sp%	0.05	0.66
	OC%	3.8	0.29
	pH	0.002	0.57
	N%	0.35	0.76
	P (mg·kg^{-1})	0.03	0.78
	K (mg·kg^{-1})	0.96	0.12
	Ca (mg·kg^{-1})	8.76	0.09
	Mg (mg·kg^{-1})	0.35	0.48
	BD (g·cm^{-3})	0.000	0.77

Table 5. Comparing soil properties between gaps and adjacent closed canopy in different depths of soil in *Fagus orientalis* forest

Depth (cm)	variables	F	P-value
0-10	Sp%	0.234	0.055
	OC%	0.005	0.781
	pH	1.850	0.790
	N%	0.028	0.679
	P (mg·kg^{-1})	7.79	**0.036**
	K (mg·kg^{-1})	7.13	0.117
	Ca (mg·kg^{-1})	0.661	0.496
	Mg (mg·kg^{-1})	4.165	0.277
	BD (g·cm^{-3})	3.835	0.213
10-20	Sp%	0.801	0.828
	OC%	0.843	0.376
	pH	4.069	0.329
	N%	0.033	0.549
	P (mg·kg^{-1})	1.951	0.291
	K (mg·kg^{-1})	4.467	0.325
	Ca (mg·kg^{-1})	5.729	**0.038**
	Mg (mg·kg^{-1})	9.276	0.228
	BD (g·cm^{-3})	0.477	0.178
20-30	Sp%	1.047	0.986
	OC%	11.638	0.133
	pH	1.512	0.258
	N%	0.120	0.636
	P (mg·kg^{-1})	5.195	0.290
	K (mg·kg^{-1})	1.636	0.406
	Ca (mg·kg^{-1})	12.88	0.84
	Mg (mg·kg^{-1})	10.93	0.739
	BD (g·cm^{-3})	1.216	0.367

Discussion

Prescott (2002) indicated that the removal of the canopy during forest logging induced changes in nutrient cycling. However; our results showed no prominent difference in terms of the most investigated soil parameters within gaps and the under-closed canopy eight years after harvesting (Tables 1, 2). Therefore, the results of the study rejected both hypotheses about created gaps and their size effects on soil properties. Our results are consistent with Ritter and Bjørnlund (2005) who reported that organic material of the soil is not affected by gap creation in *Fagus sylvatica* stands in central Zealand, Denmark. Besides, Bauhus (1996) demonstrated that the soil organic material would not change in a short period of time (twenty-one months) after gap formation in beech forest in Solling area. The results showed that organic material did not change significantly eight years after gaps creation. Therefore, it is expected that the total amount of nutrients which have been produced by the decomposition of this material, too, have not changed. Scharenbroch and Bockheim (2007), the same way, showed that gaps and forest plots had no significant differences in terms of soil organic matter and extractable P in northern hardwood-hemlock forests, Midwestern USA. Similarly, Zhang and Zhao (2007) found no significant difference of soil pH between gaps and closed canopy in broad-leaved *Pinus koraiensis* forests. Contrary to the present results, Zhang and Zhao (2007) signified that organic matter, total nitrogen, and total potassium in gap were higher than those in under closed canopy. Zhu et al. (2007) suggested that the topographical factors would affect the soil water content. Our study area is located on the slope (30%) and the water is always running through the gaps and the adjacent undisturbed stands. Consequently, the lack of significant difference between gaps and the closed canopy might be due to physiographic element. In all depths, the balk density in closed canopy is higher than those in gaps. However; only in depth of 10–20 cm the difference was significant. This result is compatible with the results obtained by Zhang and Zhao (2007) who reported that the BD in 0–10 cm of the closed canopy was higher than that of gaps in broad-leaved *Pinus koraiensis* forests.

Our results also indicated that the size of the gap had no effect on estimated soil properties (Table 1). Contrarily, Muscolo et al. (2007) found that the size of gap has effect on organic matter and soil moisture in *Abies alba* stands. Also, Muscolo et al. (2010) showed that gap size influences on C, N and P cycles.

As the single-tree selection system was applied in our studied region, the size of the created gaps was not very large. It is suggested that the natural forest ecosystems are resistant to small scale disturbances that is also claimed by Ritter and Bjørnlund (2005). Therefore, these results indicate that the created gaps by single-tree selection system have no negative effects in given forest ecosystem regarding investigated parameters.

Conclusions

This paper investigated the effect of artificial gaps created under single- tree selection system in beech stand on some soil features and its comparison with undisturbed adjacent stands. According to achieved results, it can be concluded that there is relative similar condition among gaps and closed adjacent stands in terms of soil properties eight years after harvesting in the beech stand. Therefore, applied silvicultural system for harvesting trees that create these gap size classes might be suitable for conservation and management of forests in the region. Management of deciduous broadleaved forests under selection system appeared to be sustainable and keep away from some of silvicultural troubles associated with managed forests in northern Iran. So, when foresters want to extend and preserve an uneven aged structure and soil quality in Hyrcanian beech stands, single-tree selection system can be suggested as prudent durable harvesting one.

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